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Japan Nuclear Energy Safety Organization:

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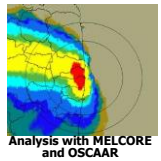
International Research
– Post-Fukushima Research



Analysis with MELCORE and OSCAAR

Post-Fukushima Research in Japan

Presented by
Masashi HIRANO
Japan Nuclear Energy Safety Organization (JNES)

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Major Contributors

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- JNES
  - Harutaka Hoshi
  - Akitoshi Hotta
  - Hideharu Sugino
  - Ryuji Kubota
  - Masami Kato
  - Norikazu Yamada
- Japan Atomic Energy Agency (JAEA)
  - Masashi Iijima
  - Toshimitsu Homma
  - Hideo Nakamura

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JNES Current Status of Fukushima Dai-ichi

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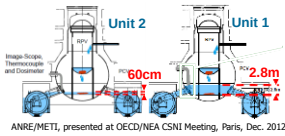
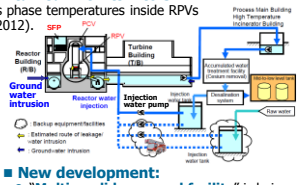
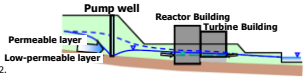
- **Stable debris cooling has been maintained in Units 1 to 3.**
  - RPV bottom temperatures and gaseous phase temperatures inside RPVs were approximately 30-50°C (Nov. 6, 2012).
- **Visual inspection was done inside PCVs with image scope, thermocouple and dosimeter:**
  - **In Unit 2**, max. radiation dose was app. 73 Sv/h and water level was app. **60 cm** from the bottom (Jan. 19 and May 26–27, 2012).
  - **In Unit 1**, max. radiation dose was app. 11.1 Sv/h and water level was app. **2.8 m** from the bottom (Oct. 9-13, 2012).



ANRE/METI, presented at OECD/NEA CSNI Meeting, Paris, Dec. 2012.



- **New development:**
  - "**Multi-nuclide removal facility**" is being implemented to further reduce the contents of many nuclides such as Rb, Sr and Co except tritium in the accumulated water.
  - "**Groundwater bypass**" is planned to reduce the ground water intrusion.



JNES Current Status of Safety Regulation

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- Only **2 units (Ohi Units 3 and 4)** are in operation (48 units in shutdown).
- **Nuclear Regulation Authority (NRA)** was established on Sep. 19, 2012:
  - NRA is establishing the new **safety standards** not only for **DBAs** but also for **Beyond-DBAs (BDBAs)** including **sever accidents** (**SAs**) by creating task teams.
  - The new standards will be applied to all existing NPPs (**backfitting**) and shall be established by July, 2013.

Draft standards cover:

- ✓ **Beyond design basis external events** to be considered:
  - **Extreme natural phenomena beyond design basis**
  - **Aircraft crash, terrorism**, etc.
- ✓ **BDBAs** to be considered:
  - Use of insights from **PRA**
    - **Accident sequences** leading to core damage
    - **Phenomena that could lead to CV failure:** Hydrogen explosion, DCH, MCCI, etc.
- ✓ **Approaches for SA measures**
  - **Robustness** against **beyond design basis external events**
  - Use of **permanently installed systems** and **mobile equipment**
  - **Reliability** and **environmental resistance/durability**
- ✓ New guides for **design basis earthquake and tsunami**

Approaches in foreign countries:
- **FLEX** concept in US
- **Hardened safety core, bunkered system**, etc. in EU

http://www.nsr.go.jp/

JNES Development of Tsunami Hazard Evaluation Methods

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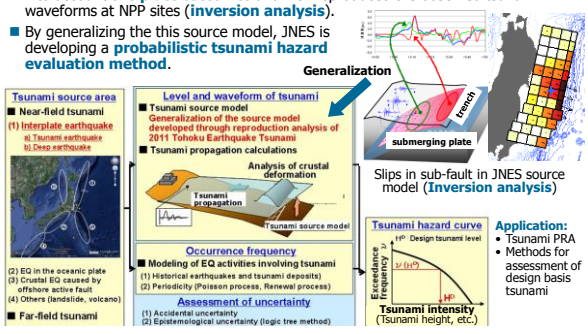
- For 2011 Tohoku Earthquake, JNES developed a **tsunami source model** taking into account **the plate tectonics** and well reproduced the observed tsunami waveforms at NPP sites (**inversion analysis**).
- By generalizing the this source model, JNES is developing a **probabilistic tsunami hazard evaluation method**.



Slips in sub-fault in JNES source model (**Inversion analysis**)

Application:
- Tsunami PRA
- Methods for assessment of design basis tsunami

Analysis of Fukushima-Daiichi (1) SA Progression and Source Terms

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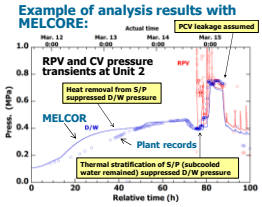
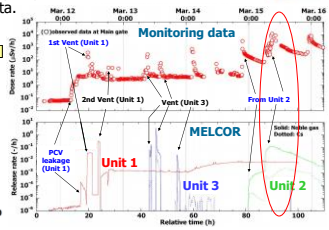
- The accident progression has been analyzed with **MELCOR** developed by U.S.NRC.
- The analysis has been improved taking into account the recent information such as:
  - leakages from RPV and CV due to **over-temperature**, and
  - **thermal stratification in S/P**.
- Release timings of FPs are relatively in good agreement with the monitoring data.

Potential Leak locations

Example of analysis results with MELCOR:





Analysis of Fukushima-Diichi Accident (2) Environmental Consequence Analysis

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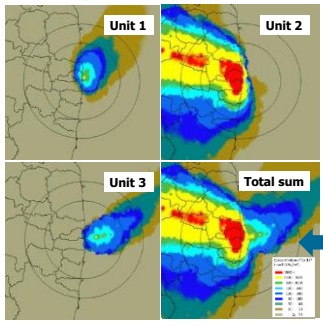
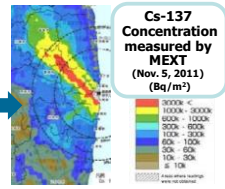
- By using the **source terms with MELCOR** (slide 6), an **environmental consequence analysis** was done in JAEA with **OSCAAR** developed there.



Major findings:

- The **release from Unit 2** on **March 15** had dominant contribution to the inland contamination.
- The release from **Units 1 and 3** mostly spread **to the ocean**.
- Sum of the release well reproduced the characteristics of the measured contamination.



Cs-137 Concentration measured by MEXT
(Nov. 5, 2011)
(Bq/m²)

Experimental Study on Scrubbing under CV Wet Venting

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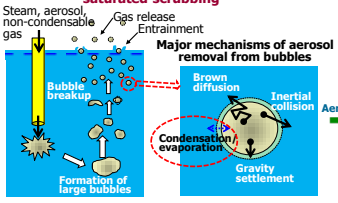
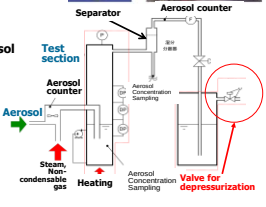
- In Fukushima accident, some peaks in the monitoring data might have been caused by CV venting. This implies that **scrubbing in S/P might have been ineffective** in reducing the release of radioactive materials.
- JNES has started a study on scrubbing under **saturated water conditions** taking into account **flashing accompanied by venting**.

Underlying physical processes of saturated scrubbing



Large Scale Integral Test

Height 10 m
Dia. 2 m
Vol. 30 m³
Max. Press. > 1MPa
Max. Temp. > 200°C



Research on Effective Cooling of Containment Vessel

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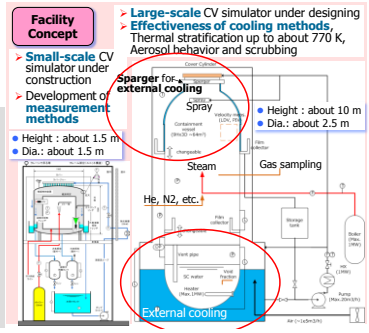
- The mission of **Nuclear Safety Research Center** (NSRC) in **JAEA** is a technical support of safety regulation.
- NSRC works on clarification of **phenomena involved in BDBAs** including **SAs** and confirmation of **effectiveness of existing and new AM measures**.

- **New test facilities on CV behavior** to start in 2013 (small-scale) and 2015 (large-scale)
  - ✓Internal and **external** CV cooling, aerosol behavior, etc
- **Detailed measurement** both inside & outside of CV
- **Development of CFD methods** for detailed phenomena clarification
- **Validation and improvement of SA analysis methods** to be used for confirmation of measures

Facility Concept

- **Small-scale** CV simulator under construction
- Development of **measurement methods**
- Height : about 1.5 m
- Dia.: about 1.5 m

- **Large-scale** CV simulator under designing
- **Effectiveness of cooling methods**, Thermal stratification up to about 770 K, Aerosol behavior and scrubbing
- Height : about 10 m
- Dia.: about 2.5 m



Experimental Study on Seawater and Boric Acid Injection

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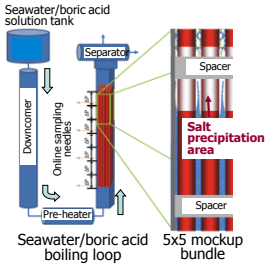
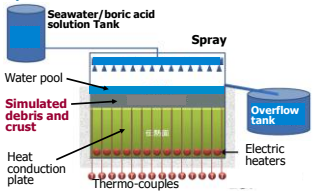
- JNES plans to conduct a study on seawater / boric acid injection to identify the **salt and boric acid crystallization/precipitation** characteristics and it's **influences on fuel/debris cooling** such as **flow blockage** for further improving AM measures.

Test for precipitation at core



Small scale test for influence on **debris cooling** at lower plenum

- Laboratory scale small test: **200mm × 200mm × 500 thickness**
- **Debris and crusts** are simulated by **alumina particles** with various diameters.



Thermal-Hydraulic Tests on LOCA at Spent Fuel Pool

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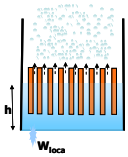
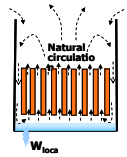
- Regarding **BDBAs at SFP**, the **draft safety standards require** that measures shall be taken to mitigate the consequence postulating **large LOCA from SFP**.
- JNES plans to conduct a study on LOCA at SFP to accumulate basic data to establish, for example, **success criteria of the fuel cooling procedures** using **spray cooling system and others available means**.

Steam flow cooling



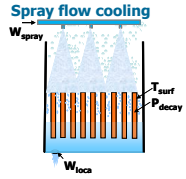
- Effectiveness of steam cooling in the case of **small LOCA** depending on the leak flow rate and fuel assembly distribution.

Air flow cooling



- Multi-dimensional natural circulation flow behavior depending on fuel assembly distribution, etc.

Spray flow cooling



- Effectiveness of spray flow cooling for **large LOCA**
- Data acquisition for assessment of models and methods

JNES Development of Evaluation Methods of Safety Culture

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- The National **Diet** of Japan Fukushima Nuclear **Accident Independent Investigation Commission** submitted the report to the Diet on July 5, 2012.
- "**Organizational issues …**" in its executive summary:
  - There were many opportunities for NISA, NSC and TEPCO to take measures that would have prevented the accident, but they did not do so.
  - The Commission found that the actual relationship lacked **independence** and **transparency**, and was **far from being a "safety culture."** In fact, it was a **typical example of "regulatory capture,"** in which the oversight of the industry by regulators effectively ceases.

http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/

- JNES has started activities for fostering **internal safety culture** and developing **safety culture evaluation methods** for both **licensees and regulatory body**.
- OECD/NEA has started a task on decision making under extreme conditions. JNES is participating in it.
- In such HOF areas, international cooperation is expected to play an important role.

- **OECD/NEA CSNI WGHOF** (WG on Human and Organizational Factors) has initiated a new task on "**Human intervention and performance under extreme conditions**":
  - **Decision making** with limited information and reduced resources under very **stressful circumstances**.
  - **Taking measures** under **extreme environmental conditions** and difficult accessibility and operability

JNES Off-site Radiological Effect on Residents and Workers

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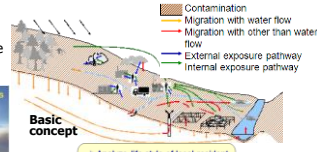
- **JNES** is conducting an evaluation of off-site radiation effects due to living and restoration activities upon request from the Local Nuclear Emergency Response Headquarters.
- **Evaluation of exposure due to wild fire**
  - About 70% area of Fukushima prefecture is forest.
  - **Simplified dose evaluation tool** applicable even under insufficient fire information has been developed and provided to local firefighter offices.

Basic concept

Assessment Method

Exposure dose = Radioactive material concentration × Terrain indicator × Land use indicator × Protective mask indicator × Wind velocity indicator × Wind direction indicator

- **Evaluation of resident exposure in decontaminated areas**



Basic concept

- Analyze life style of local resident
- Define exposure scenario
- Define exposure pathway of representative person

- Develop evaluation model
  - Migration of radioactive material
  - Exposure dose of each person
- Establishment of parameters
  - Monitoring data if available
  - From existing data base if not (Existing data will be replaced by monitoring data when available)

Dose Evaluation

JNES Summary

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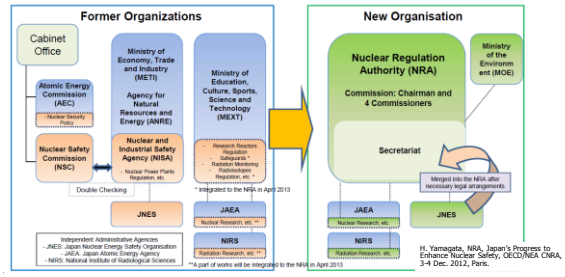
- The Diet Accident Investigation Commission pointed out "**Regulatory Capture**" as one of "fundamental causes." **Lack of technical expertise and competence** could have been a contributing factor.
  ➡ Safety research needs to contribute to **strengthening of regulatory technical bases**.
- After Fukushima, relevant acts were amended and **implementation of SA measures** becomes a **legal requirement**. NRA has established the draft new **safety standards**. JNES and JAEA/NSRC have initiated various safety research activities such as:
  - **External hazard evaluation**
  - **SA progression/source terms, effectiveness of** existing and new **SA measures**, etc.
  - **SA measures at SFPs**
  - **HOF issues** including **safety culture**
- Such topics are commonly discussed in many countries as lessons learned from Fukushima. The **international cooperation** and **sharing information** become more and more important.
  - Japan is hosting the **OECD/NEA BSAF project**, "Benchmark study of the accident at the Fukushima-Daiichi NPS", to improve SA codes and analyze accident progression and current core status in detail.

http://www.oecd-nea.org/jointproj/bsaf.html

Appendix **Reform of Nuclear Regulatory Organizations** 15

- **Independence**: To separate the functions for nuclear regulation and nuclear promotion, and to establish the "Nuclear Regulation Authority (NRA)" as an independent commission body. Chairman and Commissioners are appointed by the Prime Minister after the approval of the National Diet.
- **Integration**: To integrate nuclear regulation functions (i.e., nuclear safety, security, safeguards, radiation monitoring and radioisotopes regulation) into the NRA.

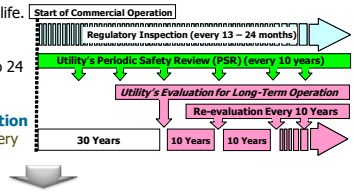


H. Yamagata, NRA, Japan's Progress to Enhance Nuclear Safety, OECD/NEA CNRA, 3-4 Dec. 2012, Paris.

Appendix **An Example of Proposed Change: Aging Management** 16

Former legislation

- There is not limit for plant life.
- Requirements:
  - **Regulatory annual inspection** every 13 to 24 months
  - Comprehensive **aging management evaluation** before 30 years and every 10 years afterwards



Proposed legislation

- **"Limit of operation" of 40 years** will be introduced.
- As an exception, **one shot extension of a certain period (<20 years)** will be approved only when compliance with the regulatory standards is confirmed.

Source: Reform of Japan's Nuclear Safety Regulation, January, 2012